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INTENSIVE STUDIES OF LOCAL CONDITIONS AS AN AID TO FORECASTING FIRE WEATHER.[1]

By GEORGE W. ALEXANDER.

[Weather Bureau Office, San Francisco, Calif., Sept. 19, 1923.]

As is well known, certain meteorological conditions are exceptionally favorable to the inception and the spreading of fires in the forested regions of this country. These conditions, although varied and due at times to somewhat different causes, have come to be known, for lack of a better term, as "fire weather." Research and analytical studies of the data accumulated during a period of years, by members of the Forest Service, have shown that fire-weather types may be somewhat roughly divided into three classes, namely:

1. Conditions actually causative of fires, that is, storms accompanied by lightning.
2. Conditions favorable for the inception of fires, however caused; these are marked by periods of unusually low absolute humidity and high temperatures.
3. Conditions favorable for the spreading of small fires, and the passing beyond control of larger ones: that is, desiccating winds and other winds of from moderate to high velocities.

Any one of these three conditions may occur singly, or a combination of any two or all three may add to the difficulties of the situation.

The three classes do not include the cumulative effect of the generally high temperatures, light precipitation, and low humidities of the summer months, which reaches its climax in maxima of fires and of damage therefrom during August or September, inasmuch as the results of such conditions are patent to the observation of all concerned, are of annual recurrence, and should require no specific forecasts. This seasonal increase in the fire hazard is, however, of prime importance to the extent by which it increases the possibility of danger during the occurrence of any or all of the specific classes of fire weather.

It is the belief of representatives of the various forest conservation associations of western America and of those members of the Forest Service who are engaged in the investigation of the problems of fire prevention and fire control that forecasts of the fire-weather conditions noted above would be invaluable could such forecasts be made sufficiently accurate and be localized to such an extent as to justify reliance on them in guiding the mobilization of the fire preventive and suppressive forces of the forestry organizations, with a view to minimizing the damage resulting from such fires as may be unavoidably caused either by natural forces or by human agencies.

Forecasts for fire weather have heretofore been and are now being made by officials of the Weather Bureau, and such forecasts have undoubtedly been of a certain value. But the meteorologist knows that the reliability of a forecast depends on the amount and accuracy of the information as to prevailing conditions that is set before its maker, and that for its localization it is necessary that conditions in the actual area under consideration be known, and that by previous study such conditions be correlated with the effects of the general distribution of the elements that control the weather.

At present the forecaster has before him a synoptic weather map which shows conditions as they exist at the several stations of the weather services of the United States and Canada, and at such positions on the seas as may be indicated by reports from such vessel weather stations as are within communicating range. Most of the land stations are at a considerable distance from each other, some separated by hundreds of miles. They are located, as a rule, in centers of habitation, generally in cultivated valleys or along the coast, for the most part where artificial, rather than natural, conditions obtain. Hence the reports as to temperature, wind direction and velocity, and precipitation, as they appear on the map, are not truly representative of those conditions that exist in the forested areas. While the pressure distribution is shown as accurately as possible, taking into consideration the reduction of the observed readings of the barometer to a sea-level basis, there is still a possibility that there may be local variations in pressure sufficiently great to influence local conditions, in the spaces between stations, which do not appear on the map. Hence the sectional forecasts for wind directions and force, while justified in general, may be altogether inapplicable to a certain specified forest therein. For the forest areas are, as a rule, located on the rugged slopes of the great mountain chains of the West, and in the intervening valleys, at elevations varying by thousands of feet. As is known to the most casual investigator, topography influences local weather conditions by its effects on the surface air currents and on the temperature of the air itself almost in direct proportion to its diversity and ruggedness. All of which adds to the difficulty of the forecaster's problem, that of indicating specific conditions in a limited locality from information of a very general character.

A somewhat similar condition for a long time obtained in the matter of forecasting frost, or damagingly low temperatures, for the benefit of those fruit growers who practice orchard heating during the winter and spring months. But this problem has been quite successfully attacked, and a high percentage of accuracy in forecasting minimum temperatures and the hour of occurrence of damaging temperatures has been obtained in several districts in California, Washington, Oregon, and elsewhere. Intensive studies of local conditions, made by trained observers, have been the means to this end. The forecast for temperature that is issued to interested parties in the fruit-frost districts does not depend only on conditions as they are shown on the general weather map, but is modified

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by what the field observer has learned of the peculiarities of the local situation and their relation to the general scheme of things. And it has been found, during this frost work, that local topography, by its influence on air currents and humidity, causes changes in local conditions to such an extent that widely varying forecasts are sometimes required for two almost contiguous sections, and that within a section points but a few miles distant from each other vary greatly as to minimum temperatures, according to their relative situation. The forecasts are becoming more reliable from season to season with the collection and analysis of additional data.

While the analogy between forecasting minimum temperatures and forecasting fire weather is by no means complete, it is sufficiently so that in studying the problems arising under the latter head the query naturally arises, "Will not a somewhat similar method of attack produce similarly favorable results?" And the conclusion is that there exists so much of a possibility of favorable results that to make the experiment is well worth while.

Thanks to the researches of various members of the national Forest Service we know exactly what we wish to attempt, which simplifies matters considerably. That is, we desire to forecast thunderstorms, both local and general, and to determine in advance, if possible, the probability of comparatively light or heavy precipitation accompanying a given storm; to forecast, a day or so in advance, a period of unusually low humidity with its consequent lowering of the moisture content of the duff and litter of the forest floor; and to predict reliably the changes in force and direction of the winds in the different sections of the forest.

There is reason to believe that, with sufficient local data to supplement that of the general weather map, such results may be accomplished, in certain areas at least. This may not be possible during the first season's work, but should be within a reasonable time, for much observational and analytical study of the topographical and meteorological peculiarities of the regions involved will be entailed, all of which will require time and patience.

A tentative outline for such a project has been prepared. Whether or not it can be put into operation depends on the appropriation of the funds necessary for procuring the required instrumental equipment and defraying the expenses for salaries, transportation, and the like, incidental thereto. Considerations of economy will also dictate that until the feasibility and value of such an undertaking have been fully determined the experiment be limited to three or four selected areas, which would undoubtedly be those concerning which the greatest amount of information is now available, and where there may be the greatest possibilities of cooperation between the workers of the Forest Service and those of the Weather Bureau.

To inaugurate such a survey will be no light task. It will require the services of at least one trained meteorologist in each area, supplemented by the assistance of local members of the Forest Service or such others as may be available.

Aside from the more immediate results of a comprehensive series of meteorological observations in the forest that may be expected from such a course, a wide and fascinating field of study is opened. The greatest single cause of forest fires is lightning. Lightning fires vary in number from year to year but for one decade in California, as stated by Messrs. Show and Kotok in their very comprehensive paper on forest fires in California for the period 1911–1920, they aggregated 41.5 per cent of the total number of fires. Such fires are the result both of local storms, most numerous in certain areas that have been tentatively defined by these investigators, and also of the general storms that cross the continent from west to east. Individual storms of the latter class have at times been responsible for great numbers of fires scattered over a wide area—over 300 per storm having been recorded on at least two occasions—with a consequent overtaxing of the fire-control system of the Forest Service and proportionately great public loss, both in the cost of control of the resultant conflagrations and in the value of the timber destroyed. Here we have a pressing incentive to the detailed study of such phenomena, so that we may devise means of giving sufficient warning to the responsible services that fire preventive and suppressive forces may be mobilized in time to minimize the damage from such fires, as their prevention, naturally, is not possible. We have ample information as to the origin and causes of thunderstorms and the weather types during which they are most common. It therefore seems quite within the realm of possibility that, having adequate local data as to air movements and humidity, together with the general information afforded by the synoptic chart, we may determine that certain combinations of conditions will or will not result in thunderstorms over a given area, this some hours in advance of the actual occurrence and with a sufficient percentage of accuracy as to be of value to those concerned. Also, perhaps somewhat later, the determined moisture content of the lower air mass and the direction of the currents, with a detailed knowledge of the changes to be expected from the predetermined movements, may enable us to make a very fair forecast as to the relative amount of precipitation to be expected from a certain storm, that is, whether comparatively light or heavy over the different topographical sections of the area over which it passes. The value of a forecast of this nature, if such be found feasible, is obvious.

That combination of conditions giving us the second general type of fire weather, namely, low humidity and high temperatures, is also, in its local manifestations, the result of a combination of general pressure distribution and the influences of local topography. Given the records from a season or two of such observations as have been described and to my mind the possibilities for an accurate 12 or 24 hour forecast of these factors are most favorable. First, curves for humidity and temperature vary, in a fashion well known, during the change from the predominating influence of a HIGH to that of a LOW. This would give a working basis. To forecast ensuing maxima, with the aid of the weather map and of hygrometric formulæ which may be developed should not be unduly difficult. Here it may be said that hygrometric formulæ of real merit have been developed at widely distant stations on the Pacific coast for use in conjunction with other data available in forecasting maximum and minimum temperatures. Given, then, the expected maximum, accurate to within two or three degrees, and the necessary information as to the distribution of the centers of high and low pressure and their movements, it should be feasible to produce a curve of the expected humidity. For this factor the absolute humidity, as expressed by the vapor pressure or the temperature of the dew point, would have to be used, as tending toward a more even curve than would the percentage of relative humidity, which fluctuates so greatly with changes of temperature.

Or the evaporation factor may be used as the basis of the curve. Inasmuch as intensive investigations are at present being carried on by the Forest Service as to the relation between atmospheric humidity, as expressed by the rate of evaporation, and the moisture content of the duff and litter of the forest floor, the development of reliable forecasts of evaporation rates would be highly desirable. It is realized, of course, that evaporation is also affected greatly by the winds, so that any attempt at such a forecast would have to take into consideration the expected velocity of the air currents, their direction, and the nature of the terrain whence they come, as affecting their moisture content. Truly a complex enough problem, at first sight, but one which may well be solved—given the time and means for the proper study of its constituent factors.

On looking into the problem of forecasting the third type of fire weather—that is, winds favorable for the spreading of fires already in existence—we also find an amply complex situation. To the effects of the distribution of the centers of barometric pressure we must add the opposition to the general air movement that is afforded by the inequalities of local topography, the effects of sharp differences in temperature over contiguous areas, and the diurnal changes caused by convection during the day and the descending hill or mountain breezes at night, and, also, the intense convection caused by a widespread fire, if such be in progress. Having the weather map, however, and a thorough knowledge of the locality under consideration, the forecasting of winds should present no insurmountable difficulty.

In speaking of the use of formulæ and curves as aids to forecasting one does not wish to imply that they are by any means infallible. When properly produced, however, from reliable data, they do become of use in the delimitation of what may be expected under normal conditions. The forecaster must also take into consideration all attendant circumstances that may come or be brought to his attention, from all sources available, and then employ both his judgment and his intuition. Nor is it desired to convey the impression that completely reliable forecasts can be made from the moment that the collection of local data is begun. The number and variety of the forces that affect the weather and the difficulty in securing adequate information in advance must be considered. Time will be required for the collection of the required data and for its study and correlation.

A very general statement only of what may be attempted has been made. It would be useless and somewhat difficult to go into more specific detail. But, knowing what is required and what he must try to accomplish, and with a well-defined idea as to methods, the individual investigator will have to adapt his resources to the particular problems presented by the area to which he is assigned. And it is hoped and expected that through the cooperation of the local observer, the district forecaster, and the members of the Forest Service, the accuracy and timeliness of forecasts for fire weather may be greatly improved.

RELATION OF WEATHER FORECASTS TO THE PREDICTION OF DANGEROUS FOREST FIRE CONDITIONS.[1]

By R. H. WEIDMAN.

[Priest River Experiment Station, United States Forest Service, September 10, 1923.]

The purpose of predicting dangerous forest-fire conditions, of course, is to reduce the great cost and damage caused by forest fires. In the region of Montana and northern Idaho alone the average cost to the United States Forest Service of fire protection and suppression is over $1,000,000 a year. Although the causes of forest fires will gradually be reduced by education and law enforcement, there always will be forest fires started by lightning and other causes when conditions in the forest are dangerous. If the dangerous fire conditions, however, can be predicted a few days in advance, the fire-protection organization can be prepared to find and suppress fires when they are small and easy to control.

To predict dangerous fire conditions in the forest, it is necessary to know exactly what constitutes such conditions. The material in the forest which burns is of first interest. Taking wood as a fuel, it is clear that if wood is dry it burns readily; if it is wet it does not. The important factor in this case, therefore, is the moisture content of the materials which comprise the fuel of forest fires. Thus, if the forester knows the different degrees of inflammability of the fuel in terms of differences in its moisture content, it is possible for him to state definitely for to-morrow or the next day what influence the approaching weather will have in making it drier or wetter; in other words, more inflammable or less inflammable.

The moisture contained in duff and other débris on the forest floor is influenced, of course, by various weather elements. The materials absorb moisture chiefly from the atmosphere in the form of rain and humidity. In summer it is largely the relative humidity of the air which causes changes in the moisture content of the materials. Duff, which is the layer of matted needles on the forest floor, especially responds to the changes in relative humidity. With high relative humidity at night the duff is relatively damp; with low relative humidity in the daytime, it becomes dry. When the relative humidity is consistently low for several days in succession, the duff loses more and more of its moisture—sometimes, in the white pine forest of northern Idaho, dropping to as low as 3 per cent of its oven-dry weight.

By inflammability tests it is known that when moisture content of duff in this region is about 10 per cent the material is readily inflammable. Below this moisture content it is extremely inflammable; above it, it gradually becomes less inflammable until a moisture content of about 17 per cent is reached, when it is difficult for a camp fire to spread readily in this material. When duff has a moisture content of 25 per cent it would be difficult for large forest fires to spread.

As relative humidity is the most important factor in changing the inflammability of forest materials in summer, the question may be asked: "Why not use relative humidity as an index?" The answer is that relative humidity does not always indicate moisture content consistently, for the reason that changes in moisture content of woody materials lag behind changes in relative humidity of the air. Another disturbing element here is temperature of the air. In nature the three elements—relative humidity, temperature, and moisture content of materials—are rarely in equilibrium. Moreover, there is an infinite variation in their relations, as a result of not being in equilibrium. A few actual measurements will illustrate this better than words. The first part of the following tabulation shows the temperature, relative humidity, and existing moisture content of duff as measured at the Priest River Experiment Station; the second part shows the moisture content of wood in

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